A large part of chemistry, and science in general, involves taking precise measurements, and so over the years people in the international community decided it would be best to have a common system where things could be measured. In 1960, the **SI Units** (from the French translation *systéme international*), a modern version of the metric system, was created. It gives us a way to take every possible type of measurement, which are:

SI Base Units		
Quantity Name	Unit Name	Unit Symbol
mass	gram	(g)
volume	liter	(L)
length	meter	(m)
time	second	(s)
temperature	kelvin	(K)
amount	mole	(mol)
electric current	ampere	(A)
luminous intensity	candelas	(cd)

These are known as the **base units**, since these are the most fundamental units of measurements. (Note: liters are not considered a base unit, but still used a lot.)

Here are some examples of these measurements being used:

- "I'm so smart, it only took me three *seconds* to solve the first question!"
- "I don't want to walk home, my house is 1,500 *meters* away!"
- "Cosmo is a super fat cat; he has a mass of 60 *grams*!"

Now, let us consider what happens when we have either a large or a small amount of one of these units. For example, what if we have a distance of 1,500 m? That is a lot, and it will become cumbersome to constantly write this out every single time, so the international community also developed **conversion factors**, which are nothing more than convenient ways to express our measurements.

Let's stick with the same example: 1,500 m. A really convenient way to express this is in terms of *kilo*meters, with an emphasis on the **prefix**. For this specific prefix, there are 1000 meters in 1 km, so we can convert *from* km *to* m by doing the following calculation:

$$1500 \text{ m} = (1500 \cancel{\text{m}}) \left(\frac{1 \text{ km}}{1000 \cancel{\text{m}}} \right) = 1.5 \text{ km}$$

This is a technique known as **dimensional analysis** (remember from Dr. Rowek?), and it makes it easy to convert from one scale to another. See how the m cancel out?

Another way to see this is that there are 10^3 m in 1 m, and this is the main idea: *all of these prefixes are used to express the units relative to the base units.* There are many other prefixes that can be used, and so here are the most common ones:

SI Prefixes

Prefix	Symbol	Multiplication Factor	... in Scientific Notation
giga	G	1 000 000 000	10^9
mega	M	1 000 000	10^6
kilo	k	1000	10^3
deca	da	10	10^1
–	–	1	10^0
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	µ	0.000 001	10^{-6}
nano	n	0.000 000 001	10^{-9}

Don't forget that there are a lot more, but for the purposes of introduction, there is no point in having them all here.

This can seem daunting at first, but as long as you remember that these are meant to simplify the base units, it makes more sense. Do not get confused with the multiplication factors; for example, look at the second row of the table, which deals with the prefix *mega*. We see that the multiplication factor is given by 10^6, so this means that there are 10^6 base units in a single mega unit; there are **NOT** 10^6 mega units in a single base unit!

Another important thing to see from this table: except for *deci* and *centi*, the powers of 10 for each are either increasing or decreasing by 3, meaning that the next prefix is 1,000 times greater than the previous! For example, if you had 2,500 Mm, then you would have 2.5 Gm.

Now, as you know, the SI Units are not the only units out there. Namely, the United States uses the **US Customary Units** for their measurements, and is includes measurements such as inches, feet, miles, cups, ounces, and more. Here are some common ones to know:

United States Customary Units				
Quantity	Unit	Symbol	Divisions	SI Equivalent
length	1 inch	(in)	-	25.4 mm
	1 foot	(ft)	12 in	0.3048 m
	1 yard	(yd)	3 ft	0.9144 m
	1 mile	(mi)	5280 ft or 1760 yd	1.609344 km
volume	1 cubic inch	(in^3)	-	16.387064 mL
	1 cubic foot	(ft^3)	1728 in^3	28.316846592 L
	1 teaspoon	(tsp)	-	4.92892159375 mL
	1 tablespoon	(Tbsp)	3 tsp	14.78676478125 mL
	1 fluid ounce	(fl oz)	2 Tbsp	29.5735295625 mL
	1 cup	(cp)	8 fl oz	236.5882365 mL
	1 pint	(pt)	2 cp	473.176473 mL
	1 quart	(qt)	2 pt	0.946352946 L
	1 gallon	(gal)	4 qt	3.785411784 L
mass	1 ounce	(oz)	-	28.349523125 g
	1 pound	(lb)	16 oz	453.59237 g
	1 ton	-	2000 lb	907.18474 kg
time	1 minute	(min)	-	60 s
	1 hour	(hr)	60 min	3600 s
	1 day	-	24 hr	-

The USC units cannot be scaled easily by factors of 10 (for example, there are 16 cups in a gallon). It is also tedious to translate between SI units and USC units. For this reason, even though we are used to the USC units, in chemistry you will almost always be using SI units, so they are important to know.

Examples

As you should know, the best way to learn is by doing, and so here are a few practice problems:

1. Convert 2.7 km to cm.

$$2.7\text{ km} = (2.7\ \cancel{\text{km}}) \cdot \underbrace{\left(\frac{10^3\ \cancel{\text{m}}}{1\ \cancel{\text{km}}}\right)}_{1\text{ km}=10^3\text{ m}} \cdot \underbrace{\left(\frac{1\text{ cm}}{10^{-2}\ \cancel{\text{m}}}\right)}_{1\text{ cm}=10^{-2}\text{ m}} = 2.7 \times 10^5\text{ cm} = 270000\text{ cm}$$

2. Convert 9 kg to ng.

$$9 \text{ kg} = (9 \cancel{\text{kg}}) \cdot \underbrace{\left(\frac{10^3 \cancel{\text{g}}}{1 \cancel{\text{kg}}}\right)}_{1 \text{ kg}=10^3 \text{ g}} \cdot \underbrace{\left(\frac{1 \text{ ng}}{10^{-9} \cancel{\text{g}}}\right)}_{1 \text{ g}=10^{-9} \text{ ng}} = 9 \times 10^{12} \text{ ng}$$

3. Convert 3.45 L to gallons.

$$3.45 \text{ L} = (3.45 \cancel{\text{L}}) \cdot \left(\frac{1 \text{ gal}}{3.785411784 \cancel{\text{L}}}\right) = 0.911 \text{ gal}$$

4. Suppose you are an American tourist visiting your relatives in Europe. As you are driving, you see a sign that say the speed limit is 40 km/hr. You have no idea what it means, but since you are a chemistry student, you know how to convert. What is the speed limit in mi/hr?

$$40 \text{ km/hr} = \left(\frac{40 \cancel{\text{km}}}{1 \text{ hr}}\right) \cdot \left(\frac{1 \text{ mi}}{1.609344 \cancel{\text{km}}}\right) = 25 \text{ mi/hr}$$

5. You just bought a laptop with a storage space of 256 Gb of memory, where b stands for *byte*, a unit of digital information.

   (a) How much memory does your computer have in Mb?

$$256 \text{ Gb} = (256 \cancel{\text{Gb}}) \cdot \left(\frac{10^9 \cancel{\text{b}}}{1 \cancel{\text{Gb}}}\right) \cdot \left(\frac{1 \text{ Mb}}{10^6 \cancel{\text{b}}}\right) = 256 \times 10^3 \text{ Mb}$$

   (b) Let's say you have 50 pdf documents that you want to download them all to your computer. For the sake of example, suppose they all have a document size of 50 Mb. In Gb, how much space would all 50 of these documents take up?

$$\left(\frac{50 \cancel{\text{Mb}}}{1 \cancel{\text{file}}}\right) \cdot \left(\frac{1 \text{ Gb}}{10^3 \cancel{\text{mB}}}\right) \cdot (50 \cancel{\text{files}}) = 2.5 \text{ Gb}$$

   (c) Suppose your laptop downloads these files at a rate of 20 Mb/s. What is the rate in Gb/min? How long, in minutes, will it take to download the 50 files?

$$20 \text{ Mb/s} = \left(\frac{20 \cancel{\text{Mb}}}{1 \cancel{\text{s}}}\right) \cdot \left(\frac{1 \text{ Gb}}{10^3 \cancel{\text{Mb}}}\right) \cdot \left(\frac{60 \cancel{\text{s}}}{1 \text{ min}}\right) = 1.2 \text{ Gb/min}$$

$$(2.5 \cancel{\text{Gb}}) \cdot \left(\frac{1 \text{ min}}{1.2 \cancel{\text{Gb}}}\right) = 2.1 \text{ min}$$